

June 6, 1956

Dear

50X1

Transmitted herewith is our Final Report on Rocket Evaluation, June 4, 1956. We hope this report meets with your approval, but if further information is desired, please let us know.

Regards,

50X1

Enclosures:

5 Copies of Report  
2 Copies of Receipt

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June 4, 1956

F I N A L   R E P O R T

ON

ROCKET EVALUATION

1210-E-6a

Contract No. HD-45

Research Order No. 3

50X1

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I. ABSTRACT

One hundred (100) rockets were received loosely packed in two boxes. A preliminary examination disclosed poor quality and workmanship. Measurements of the center of gravity and calculations of the expected range indicated a poor performance. The individual parts had a large variance in size and the propellant weight was not constant from one unit to another.

During static tests, one unit had a deflected jet for a portion of the burning time and had a total burning time variance of 20 per cent with another unit. Of three groups of flight tests, only one unit flew with any degree of success. Others exhibited various types of erratic behavior including premature bursting 25 feet from the launching site. In general, the range, flight stability, and performance of these rockets is so poor as to make them totally unfit for their proposed task.

## II. INTRODUCTION

One hundred (100) disassembled rockets were received at Station I for evaluation testing. These were received in one large unmarked crate. Inside was a smaller box of motors, very loosely packed and another box loosely packed with sticks, fins, ogives and body tubes. No instructions were included. The parts in both boxes were not segregated or packed with any protection against damage during transit, as may be seen in Plates 1 and 2. A partially obliterated label on one interior crate disclosed the original departure point.

A test program was planned to determine component composition, range and flight characteristics, payload capacity, effects of temperature on performance and design details.

Preliminary examination of the units disclosed poor quality of materials and poor workmanship. Many of the parts did not fit, being either too tight or too loose. Considerable dissimilarity in size was noticed in the same type part.

All the components were measured so that engineering drawings could be made from the average of these measurements.

### III. ANALYSIS

#### A. Physical

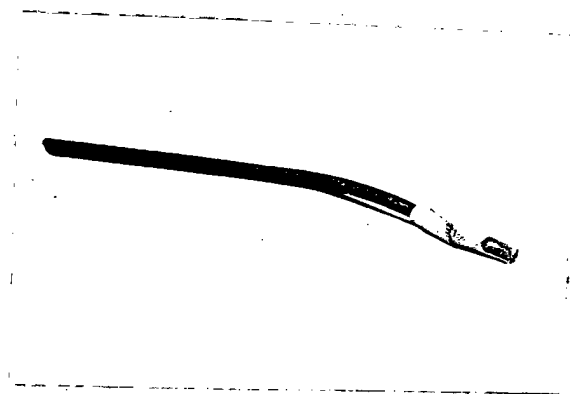
The motor section is a tube of paper laminated phenolic material 1-11/32" O.D., 1-3/16" I.D. and 7-1/2" long, shown in Drawing No. 401. Three fin holders made of varnished cardboard are spaced 120 degrees apart around the nozzle end of the motor tube. Two guide tubes, also of varnished cardboard, are spaced 180 degrees apart between the fin holders. Both the fin holders and the guide tubes are glued and clamped to the motor section.



The nozzle plate is a wooden disc glued to the inside of the motor tube  $3/16$ " from the end. The disc, shown in Drawing No. 404, is  $1/4$ " thick with a  $0.325$ " hole, which in many cases is drilled off center. In contact with the nozzle plate and each other are four separate layers, referred to as layers 1, 2, 3, and 4 commencing with the layer next to the wooden disc. Each appears to be pressed in place, one on top of the other, as shown in Drawing No. 401.

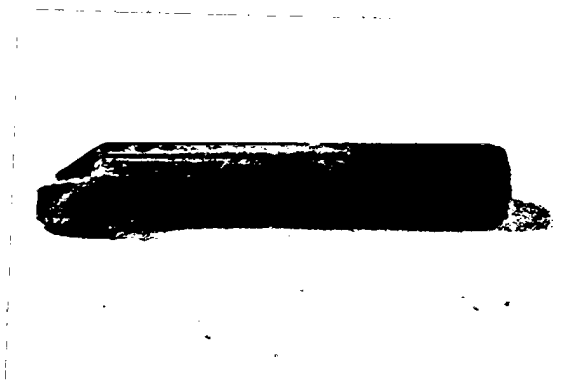
Layer No. 1 is  $1-5/16$ " long and has a  $0.325$ " hole drilled through it, concentric to that in the nozzle plate. This material is non-combustible up to 1000 Deg. C and apparently acts both as a plug for the propellant and as a nozzle. Layer No. 2 is  $2-7/8$ " long and appears to be a modified, compressed, black powder. Layer No. 3, which is  $5/8$ " long, is of the same composition as Layer No. 1 and serves to separate the propellant from the bursting charge. A  $3/16$ " hole has been drilled through this layer and is filled with the same material as the No. 4 layer, the bursting charge. Apparently, the No. 3 layer also serves partially as a plug to help contain the burst within a smaller volume. The No. 4 and final layer is  $3/16$ " long and is very similar to A-4 or A-5 unglazed black powder. This layer is separated from the payload compartment by a thin cardboard disc.

The fuze is a  $1/4$ " X 7" length of black cord resembling Bickford Fuze and takes approximately 22 seconds to burn. The fuze is inserted through the wooden nozzle plate and the hole in Layer No. 1. A piece of gummed paper tape is wound around it at the point where it enters the wooden nozzle to wedge it in place. The section of fuze from the wooden nozzle plate to the propellant is coated with a tar-like substance to contain the fire and direct it onto the propellant. In all the units tested, the fuze performed well with no cases of poor ignition.



Three fin holders, made of  $1/16$ " varnished cardboard, formed into a  $1/2$ " hollow square are used to secure the fins to the motor tube as shown in Drawing No. 405. They are  $3-1/2$ " long, cut at 45 degrees on one end and slotted at both ends to hold the retaining bands. On the short

side of the tube, a  $2\frac{5}{8}$ " slot is cut to allow the fin to slide into the holder.



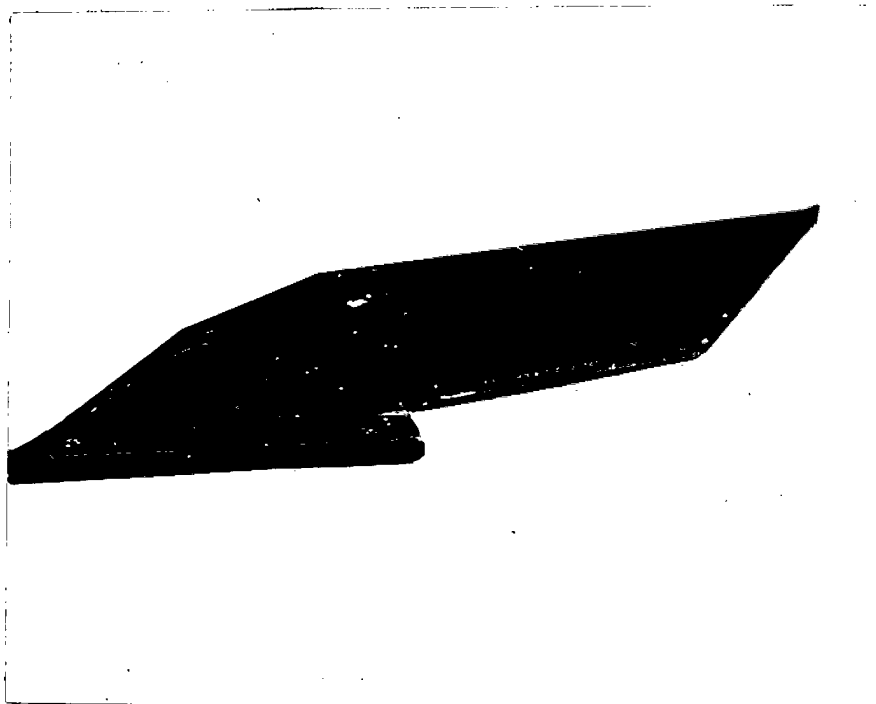
Two guide tubes, fastened to the rocket motor with the tube axis parallel to the rocket axis, are used to hold the rocket as it travels along the launching sticks. They are formed from  $7/16$ " I.D. and  $9/16$ " O.D. varnished cardboard tubing  $3\frac{1}{8}$ " long as shown in Drawing No. 405. One end is cut on a 45 degree angle and the other end is slotted to hold the retaining bands used to fasten the guide tubes and fin holders to the rocket motor. The tubes are also coated with a dark blue lacquer.



Two retaining bands, shown in Drawing No. 404, fasten the fin holders and guide tubes to the motor tube. They are  $1/64$ " galvanized steel  $3/16$ " wide. When bent they form a  $1-7/16$ " I.D. circle. The bands are held in a circular position by a  $3/16$ " cotter pin  $7/8$ " long through loops formed in the band.

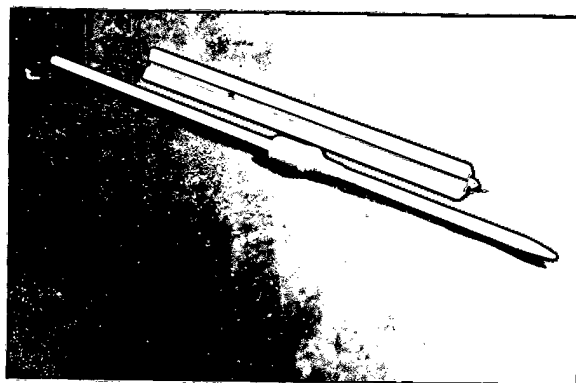


The fins, shown in Drawing No. 402, are made of stiff  $3/32$ " cardboard with two small strips of the same material riveted and glued to one edge, thus making a mounting flange. This flange fits firmly into slots cut into the fin holders fixed to the sides of the rocket motor. The fins are finished with a dark brown varnish or stain. Each fin has an area of 9.3 square inches.



Two pointed sticks, which are used to launch the rocket, fit into two hollow cardboard cylinders fastened 180 degrees apart on the body of the rocket between the fins.

The sticks, shown in Drawing No. 403, are made of hard wood  $5/16$ " in diameter and 20" long. They have a stop, made of heavy cardboard tubing 1-1/2" long,  $3/4$ " O.D.,  $3/8$ " I.D., fastened to the sticks with several turns of  $9/16$ " gummed paper tape 9" from the pointed end. The sticks are driven into the ground at the desired angle and the rocket is slid over them by means of the two guide cylinders as may be seen in Plate 3. The stops prevent the rocket from sliding down the sticks and resting on the ground.



The payload compartment, shown in Drawing No. 400, is formed of four layers of paper rolled into a tube 5-1/4" long and 1-7/16" in diameter. The outer layers are of light green and light blue paper. All the layers when rolled together and glued are 1/16" thick. The tube fits snugly over the tube containing the propellant and because of the absence of a limit line or stop, can be slid back to the fins. About one inch of overlap, however, is sufficient to secure the two tubes tightly together.

The volume of the payload space is 12 cu. in. including the space in the ogive. Assuming a one inch overlap there is 11 cu. in. in the tube alone.



The ogive, shown in Drawing No. 400, is made of laminated varnished cardboard and forms a right cone 1-5/8" in diameter at the base and 1-1/2" in height. The tip of this cone is rounded slightly. A flange that is glued into the open end of the cone slips over one end of the payload compartment. The flange is made of three layers of heavy paper rolled into a tube 1-1/2" in diameter and 3/4" long. Both ogive and flange are coated with a dark blue lacquer finish on the outside. The workmanship was poor, many units being off-centered and some were too small or too large for use.



## B. Chemical

The propellant section of the unit is composed of four layers pressed in place in contact with each other.

Spectrographic analysis of similar rocket motors indicated the presence of potassium nitrate, sulfur, carbon and clay.

An analysis scheme was planned whereby the sulfur was removed by passing warm carbon disulfide through the sample and noting the loss in weight. Similarly, the potassium nitrate was removed with warm water. The residue, consisting of clay and carbon could be ignited to remove the carbon, leaving clay as a residue.

Layers one and three were 95% insoluble and were presumed to be clay with some contaminant, such as the second layer. Layer four was very similar to A-5 unglazed black powder and no analysis was made of this layer. The second layer, which is the propellant section, was composed of 78.5% potassium nitrate, 13.0% carbon, and 8.5% sulfur, which is comparable to other formulations for a vigorous black powder.

### C. Mathematical

The weight of the complete unit, minus propellant is 215 gms., with a propellant weight of 75 gms. Assuming a low escape velocity of 1000 ft./sec. and using the familiar  $V_b = V_e \ln(1 + \frac{m}{M})$ , where  $V_e$  equals escape velocity,  $V_b$  equals burnt velocity of rocket,  $m$  equals weight of propellant, and  $M$  equals weight of rocket minus propellant,  $V_b$  equals 300 ft./sec. for a rocket carrying no payload. The flight of the rocket must terminate with the firing of the bursting charge, which takes place immediately after the propellant is exhausted. Since the average burning time is 6 sec., the rocket must travel  $\frac{0 + 300}{2}$  ft./sec. for 6 sec. or 900 ft. along the flight path, assuming a linear acceleration. If the angle of elevation of the launcher is 45 degrees, this should produce a range measured along the ground of 636 ft. A payload would reduce this range. Because of the observed performance during the flight testing of the rockets, the assumption of 1000 ft./sec. escape velocity must be in error, since no flights were achieved in excess of 200 ft.

For an empty unit, the center of gravity is located 3 inches from the nozzle end. When loaded with 100 gms. of payload in ogive, the center of gravity is 5 inches from the nozzle end. If force is applied to the side of the rocket, as is the case when the rocket yaws, a turning moment is produced on the rocket. The axis of this turning moment is perpendicular to the longitudinal axis of the

rocket and is located 6 inches from the nozzle end. This point is defined as the center of pressure. Ideally, the center of pressure should be as far to the rear of the center of gravity as possible. In the case of the Gretchen rocket, the center of pressure is from 1 to 3 inches forward of the center of gravity, depending on the load. This produces a tendency for very unstable flight characteristics, a condition observed during flight tests.

#### D. Performance

For static tests the motor sections were clamped in a vise which was fastened to the ground at the test site. Two units were static tested. The first unit was easily ignited and burned for 5 seconds with a clearly defined jet extending 8 to 10 inches from the nozzle. At the end of this time, the bursting charge exploded, expelling the cardboard retaining the disc out of the motor tube, which was not damaged.

The second unit had the jet exhaust deflected about 45 degrees from the axis of the rocket for 0.5 seconds after ignition. After this time, the jet returned to its correct position and continued burning for 3.5 seconds at which time the bursting charge exploded, expelling the cardboard retaining disc and not damaging the motor tube. The deflected jet was probably due to a fragment of propellant causing an obstruction in the hole through the wooden nozzle plate and the first layer which apparently functions as the nozzle.

For flight testing, the first rocket was loaded with 100 gms. of payload, a weight considered more than sufficient to insure that the rocket would not leave the test area. The rocket, when fired, moved one or two feet off of the launching sticks, which were set at a 45 degree angle, then fell to the ground and moved erratically along the ground to a point 25 feet in front of the launcher before the bursting charge ended its motion. Total burning time was 7 seconds. The bursting charge separated the payload compartment from the motor compartment without much damage to either.

The second rocket was fired without a payload and also at a 45 degree angle. This rocket, with a very erratic flight path, gained 25 feet of altitude and traveled some 30 feet, measured along the ground from the launcher. After 2.5 seconds of burning, it blew up, destroying the payload compartment and splitting open the motor tube. The propellant apparently had a crack in it allowing the burning area to expand suddenly, causing an explosion.

Three of the rockets were dried in an oven for 48 hours, at 40 degrees C., to remove any moisture which might have been absorbed by the propellant during storage and shipment. These units acted in much the same manner as the previously tested rockets, although one unit with a 50 gm. payload traveled approximately 200 ft. with a flight path 15 degrees left of the launcher.

Two additional units were tested; one of which traveled approximately 100 ft.

Further flight testing was discontinued because of the poor results and the test program was reduced to determination of the chemical composition of the propellant and the preparation of engineering drawings of the units.

#### IV. CONCLUSIONS AND RECOMMENDATIONS

Little good can be said of these units, although considerable ingenuity was exercised in the use of cheap components. Many of the components had a very loose tolerance in size. Some ogives were loose enough to fall off and some motor tubes were so large that the body tube could not be slid on. The fins varied considerably in the fit in the fin holder, some being so tight as to be unusable. As much as 5 to 10 degrees variation was noticed in the fin angle.

In a random sampling of six motor units, the weight of the propellant layer varied as much as 15 per cent and the length of the motor tube by as much.

To launch the rocket, the launching sticks must be driven into the ground at some desired angle parallel to each other. On rocky or frozen ground this would present a problem. The sticks do not form a stable launching platform and whip up as the rocket leaves them. This imparts a turning movement to the rocket and increases the poor flight characteristics.

Several of the rockets were found to have a poorly centered hole in the nozzle. This produces a deflection of the jet and thus a veering of the rocket from its intended path. The misalignment of the fins and the misplacement of the center of gravity also combine to produce an unpredictable flight. The use of these rockets presents a serious safety hazard due to the erratic flight path and a tendency toward premature explosions.

V. FINANCIAL STATEMENT

Total Amount of Contract

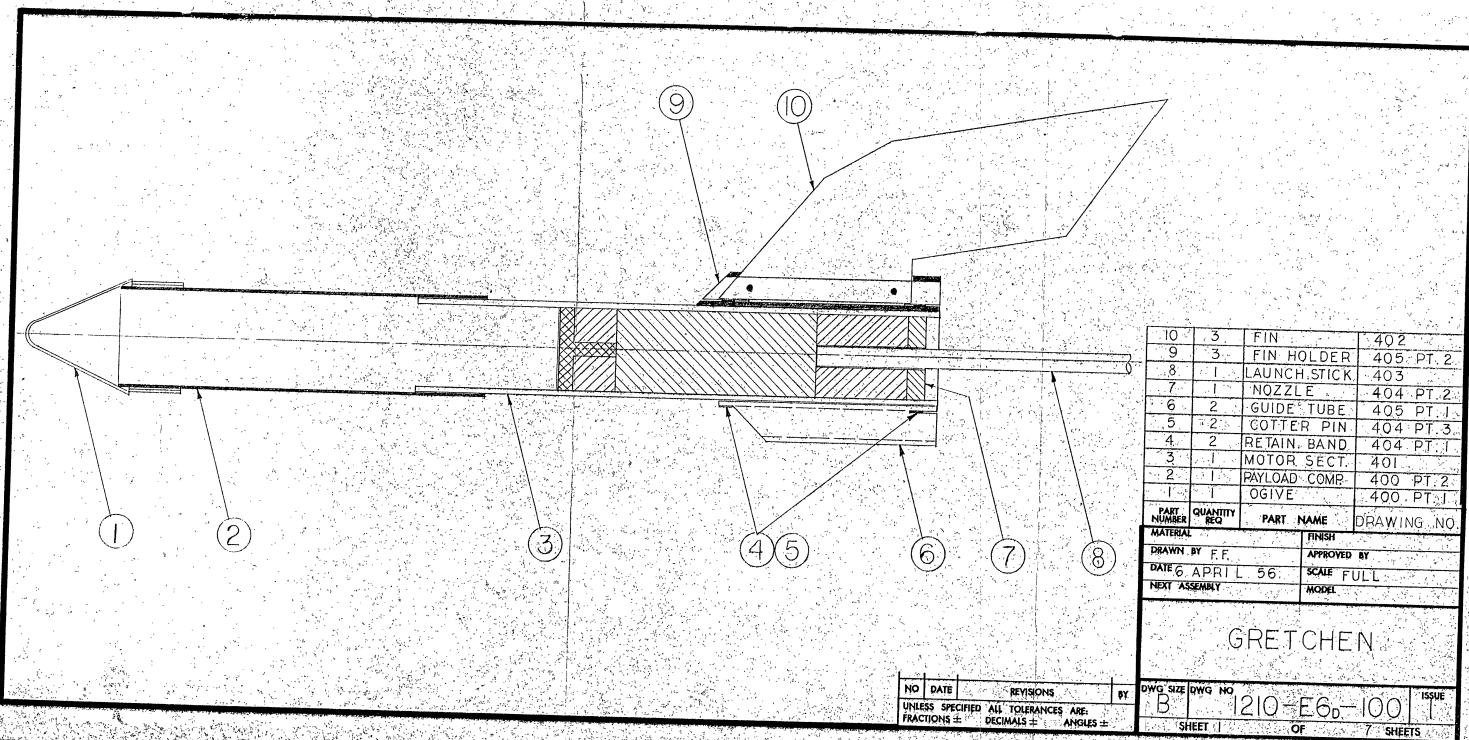
Obligations for April, 1956

Total Obligations to April 30, 1956

Balance of Contract



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10	3	FIN	402
9	3	FIN HOLDER	405 PT. 2
8	1	LAUNCH STICK	403
7	1	NOZZLE	404 PT. 2
6	2	GUIDE TUBE	405 PT. 1
5	2	COTTER PIN	404 PT. 3
4	2	RETAIN. BAND	404 PT. 1
3	1	MOTOR SECT.	401
2	1	PAYLOAD COMP.	400 PT. 2
1	1	OGIVE	400 PT. 1

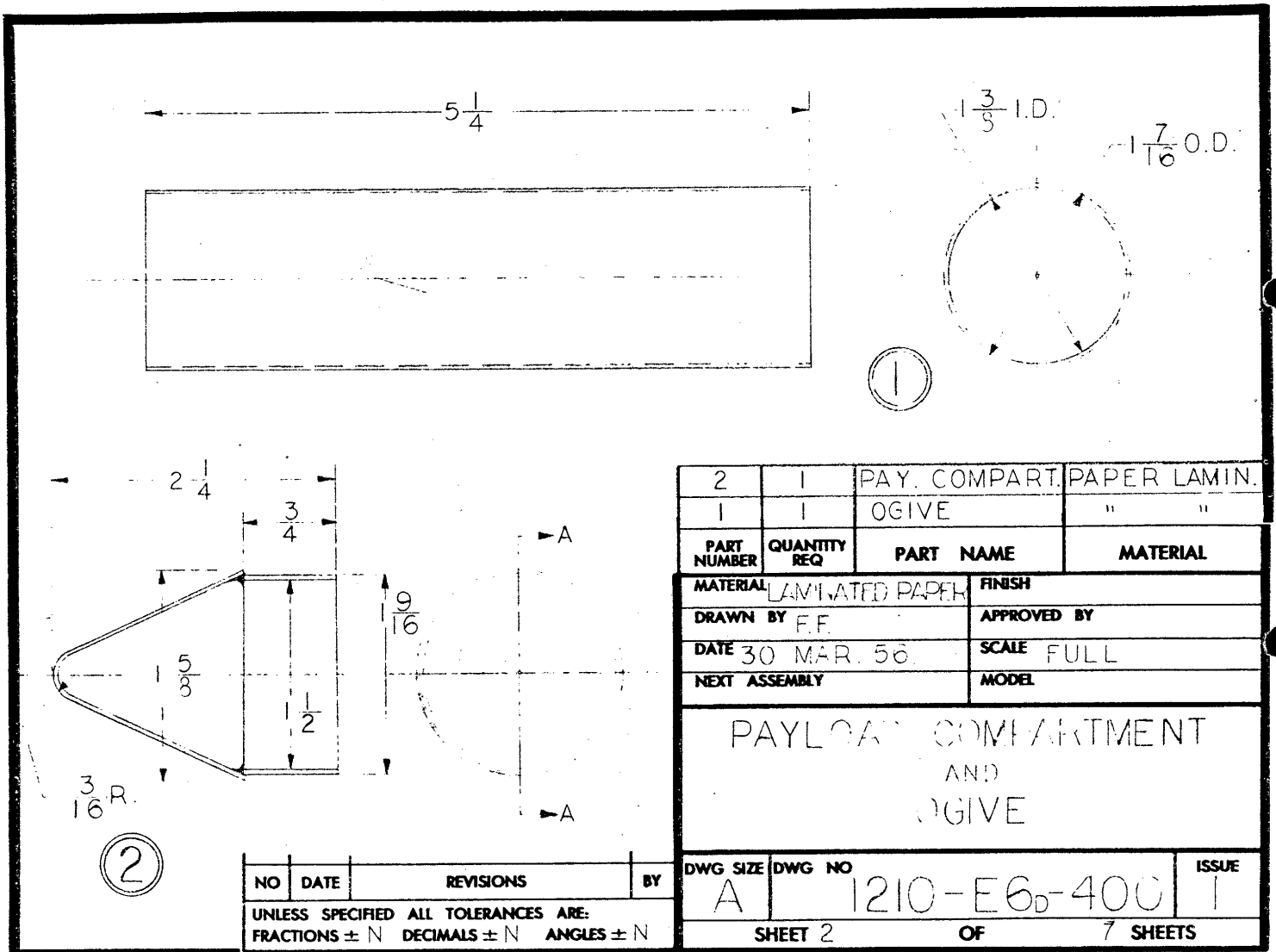
PART NUMBER	QUANTITY REQ.	PART NAME	DRAWING NO.
MATERIAL		FINISH	
DRAWN BY F.F.		APPROVED BY	
DATE 6 APRIL 56		SCALE FULL	
NEXT ASSEMBLY		MODEL	

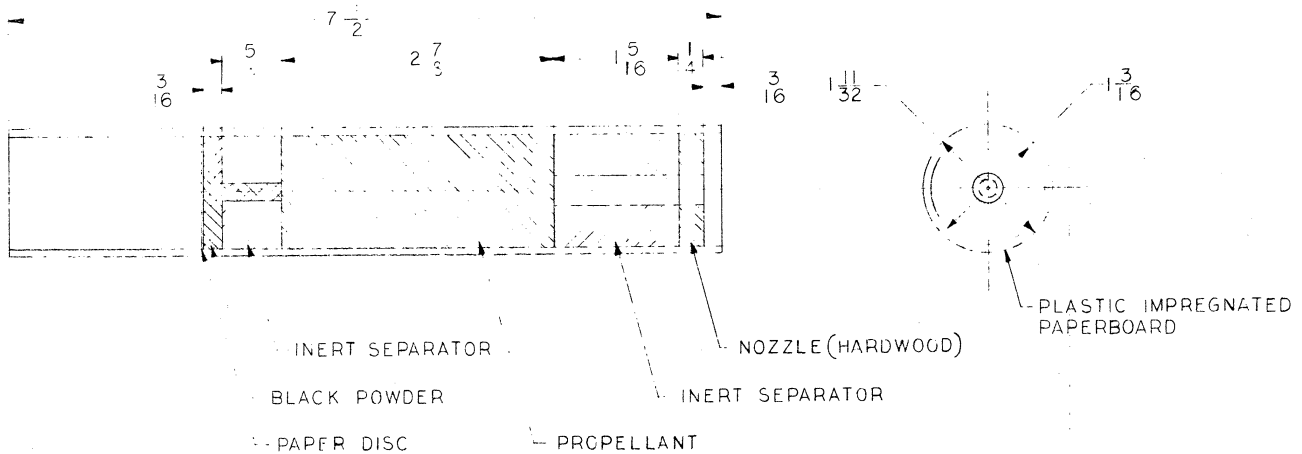
  

GRETCHEN			
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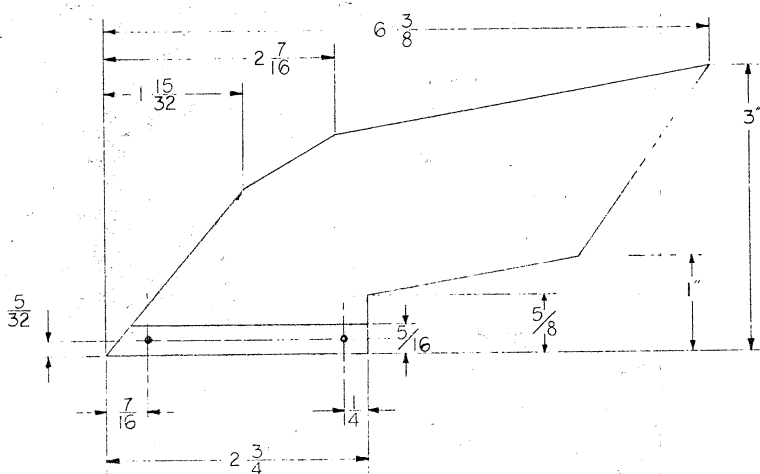
NO	DATE	REVISIONS	BY	DWG. SIZE	DWG. NO.	ISSUE
UNLESS SPECIFIED ALL TOLERANCES ARE:						
FRACTIONS ±	DECIMALS ±	ANGLES ±				
SHEET 1		OF 7		SHEETS		



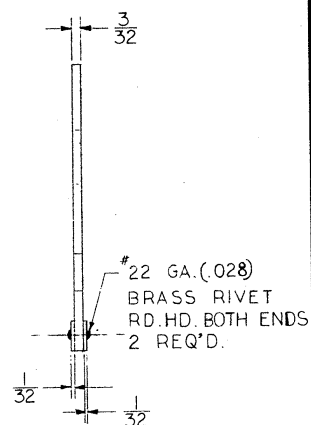


PART NUMBER	QUANTITY REQ	PART NAME	MATERIAL
MATERIAL AS CALLED FOR		FINISH	
DRAWN BY F.F.		APPROVED BY	
DATE 30 MAR. 56		SCALE FULL	
NEXT ASSEMBLY		MODEL	
MOTOR SECTION			
DWG SIZE B	DWG NO 1210-E60-401	ISSUE 1	
SHEET 3		OF	7 SHEETS

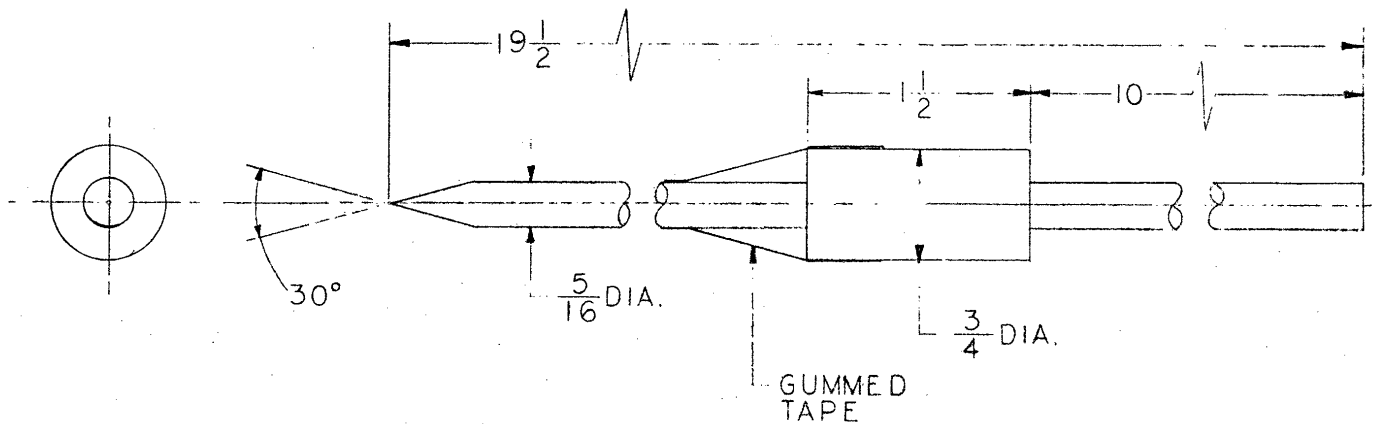
NO	DATE	REVISIONS	BY
UNLESS SPECIFIED ALL TOLERANCES ARE: FRACTIONS $\pm N$ DECIMALS $\pm N$ ANGLES $\pm N$			



3 REQ'D.



PART NUMBER	QUANTITY REQ.	PART NAME	MATERIAL
MATERIAL PAPER BOARD		FINISH	
DRAWN BY F.F.		APPROVED BY	
DATE 2 APRIL 56		SCALE FULL	
NEXT ASSEMBLY		MODEL	
FIN			
NO	DATE	REVISIONS	BY
UNLESS SPECIFIED ALL TOLERANCES ARE: FRACTIONS ± N DECIMALS ± N ANGLES ± N			
DWG SIZE B	DWG NO 1210-E6d-402	ISSUE 1	
SHEET 4		OF 7 SHEETS	



PART NUMBER	QUANTITY REQ	PART NAME	MATERIAL
MATERIAL	HARDWOOD	FINISH	
DRAWN BY	F.F.	APPROVED BY	
DATE	3 APRIL 56	SCALE	FULL
NEXT ASSEMBLY		MODEL	

LAUNCHING STICK

NO	DATE	REVISIONS	BY
UNLESS SPECIFIED ALL TOLERANCES ARE: FRACTIONS $\pm N$ DECIMALS $\pm N$ ANGLES $\pm N$			

DWG SIZE	DWG NO	ISSUE
A	1210-E6d-403	1
SHEET 5	OF	7 SHEETS

①

3 HOLES  
3/16 THK. FORMING A 1 7/16 I.D.  
CIRCLE WHEN CLAMPED

②

1/4  
.325 DIA. HOLE

③

7/8

PART NUMBER	QUANTITY REQ	PART NAME	MATERIAL
3	2	COTTER PIN	STEEL
2	1	NOZZLE	HARDWOOD
1	1	RETAINING BAND	GALV. STEEL

MATERIAL AS CALLED FOR	FINISH
DRAWN BY F.F.	APPROVED BY
DATE 3 APRIL 56	SCALE FULL
NEXT ASSEMBLY	MODEL

## BAND, NOZZLE, & PIN

NO	DATE	REVISIONS	BY
UNLESS SPECIFIED ALL TOLERANCES ARE: FRACTIONS ± N DECIMALS ± N ANGLES ± N			

DWG SIZE	DWG NO	ISSUE
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SHEET 6		OF 7 SHEETS

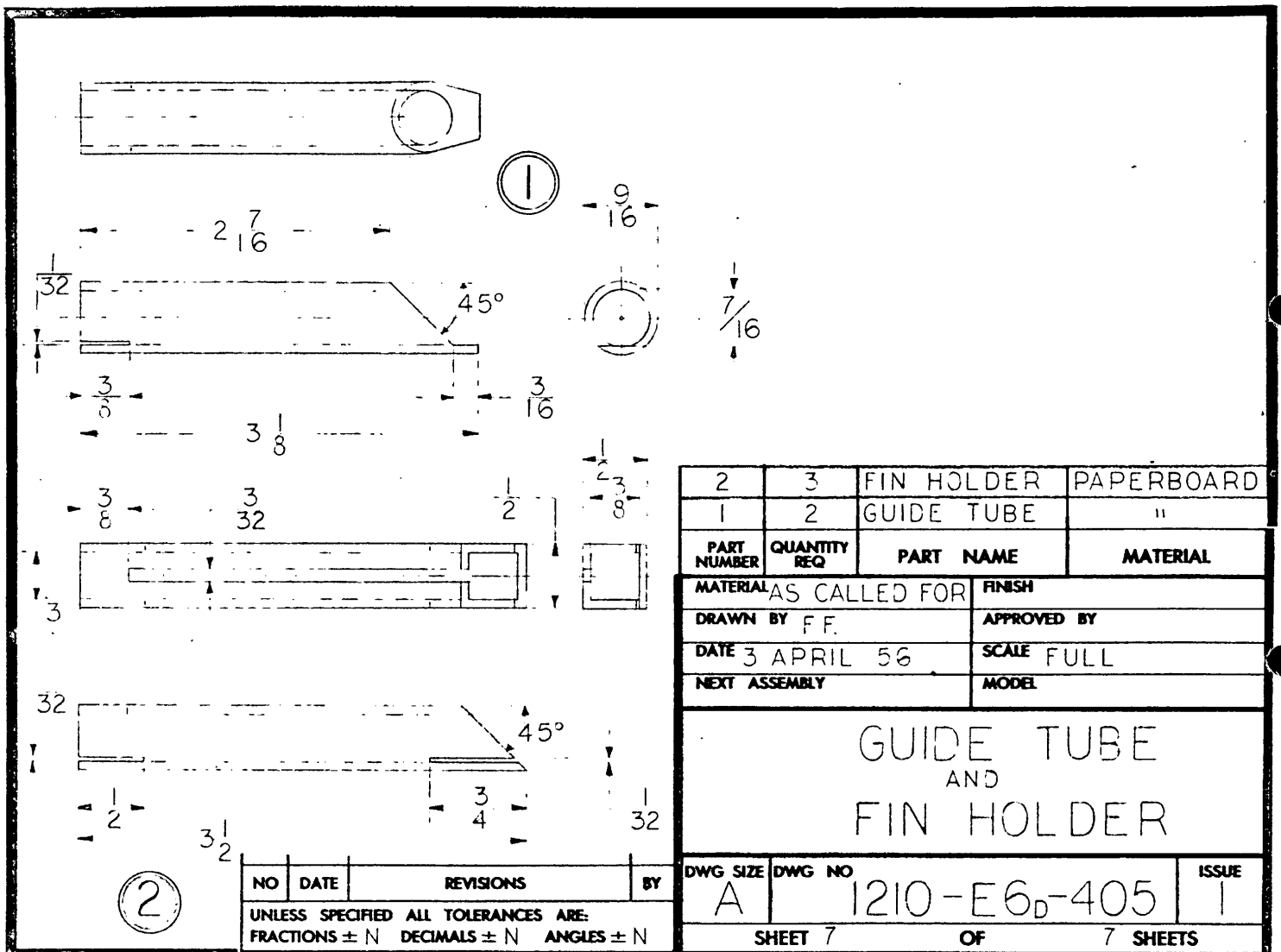




PLATE I



PLATE II



PLATE III